Sustaining the Drone Enterprise

How Manpower Analysis Engendered Policy Reform in the United States Air Force

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Abstract

The Remotely Piloted Aircraft (RPA), colloquially labeled the “drone,” has become iconic of American military campaigns this century. However, with surging demand for RPA combat operations, the United States Air Force (USAF) has struggled to train and retain sufficient manpower to operate these aircraft. Earlier efforts to address this challenge relied on military intuition and subjective input instead of objective analysis, engendering significant manpower shortfalls and jeopardizing USAF capacity to complete RPA missions worldwide. As part of a recent effort by the Secretary of Defense to stabilize manpower trends in the USAF

RPA enterprise, we developed a dynamic manpower projection model to quantify the potential impact of over fifty policy initiatives. Ultimately, the model illuminated that a combination of five major policy initiatives would most efficiently and expeditiously improve manpower trends. The Air Force has already begun to implement these initiatives as part of a plan that will affect over 1100 Active Duty airmen operating a multibillion-dollar enterprise. In this paper, we discuss the background and complexity of the RPA manpower problem, the metrics that we used to evaluate the manpower system, and the modeling techniques we employed to inform a comprehensive solution to mitigate this manpower shortfall.

Key Words: Remotely Piloted Aircraft, United States Air Force, manpower planning, pilot production, Markov chains, dynamic flow model

Introduction

Throughout the recent conflicts in Iraq and Afghanistan, defense policymakers and military officials have debated the ethics and efficacy of deploying unmanned aircraft both for “Intelligence, Surveillance, and Reconnaissance” (ISR) as well as “Strike” missions. More recently, however, the discourse surrounding Remotely Piloted Aircraft (RPA) has shifted away from the aircraft themselves and onto the pilots who operate them, an ironic refocus for an aircraft popularly defined by its lack of a manned cockpit. Indeed, the most salient question concerning these aircraft at the Pentagon today is operational, not ethical: given increasing global demand, how can the United States Air Force (USAF) produce and retain sufficient numbers of pilots to fly these aircraft?

Scoping the Problem

Building and managing a sustainable pilot production pipeline is a notorious challenge for defense analysts and manpower experts. ("Pipeline" refers to the series of training requirements a pilot must satisfy initially, including two key phases—Undergraduate RPA Training and Formal Training Units—which we explore below). With dwindling resources, military planners often face a fundamental choice between committing resources to combat operations in the short-term as opposed to building a systemically sustainable force for the long-term.

With the USAF RPA enterprise, officials grappling with this tension have historically opted for the former. Indeed, as illustrated in Figure 1 and

Table 1, continuous operations since 2004 have given Air Force officials limited recourse, as they have committed disproportionate manpower to current theater operations at the expense of building a sustainable training pipeline necessary to generate future RPA pilots. (We elucidate this tension in the sections below). With surging demand for Combat Air Patrols or "CAPs" (i.e., the combat missions flown by RPA pilots) and an inability to adequately plan for long-term missions, by 2014 the Air Force could no longer supply sufficient manpower for RPA missions by its MQ-1 "Predator" and MQ-9 "Reaper" platforms in volatile areas including Iraq, Syria, Afghanistan, and the Horn of Africa. We focus our analysis, and this paper, on this undermanned MQ-1/9 community, which comprises over 80% of the overall USAF RPA enterprise and historically has suffered the most significant manpower shortages.

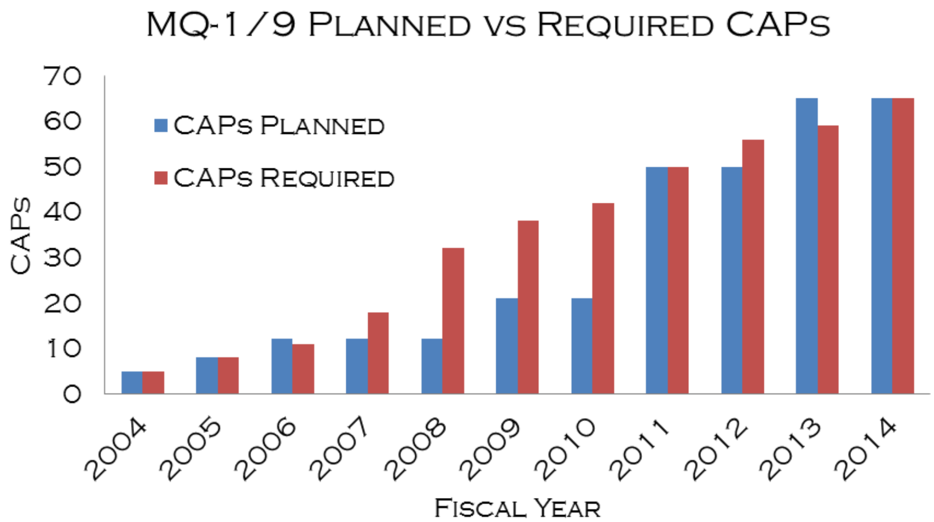

Figure 1: The chart depicts the increase in required MQ-1/9 CAPs versus planned MQ-1/9 CAPs. Air Force planners anticipated fewer CAPs than were actually required in five of the last eight years.

Table 1: The table outlines the history of MQ -1/9 operations, including many "short-term" initiatives that the Air Force implemented to achieve the number of required CAPs in each year from 2007 to 2014.

Year	Decision to Support Increased CAP Requirement	CAPs Planned	CAPs Required
2007	Extended tours, curtailed aircraft testing, mobilized (i.e., assembled for duty) Air Reserve Component (ARC), and recalled crews	12	18
2008	Implemented assignment freeze, ordered additional ARC mobilization, delayed RPA weapons school	12	32
2009	179-day temporary duty extended to 365-day temporary duty, established RPA pilot and sensor operator career field, expanded training capacity	21	38
2010	65-CAP plan starting in 2013, assignment freeze	21	42
2011	Reduced training capacity	50	50

2012	Reconstituted combat units, reduced training capacity, reduced weapons school	50	56
2013	-	65	59
2014	Reduced staff, test, and training capacity	65	65

Complexity of the System

Ostensibly, managing the RPA manpower force should be a straightforward task for Air Force planners. One might assume that, facing increasing demand for RPA missions, the Air Force could simply recruit and train additional pilots to parallel the growing requirement. But myriad factors—including competing demands from other mission areas, technical difficulty of training, length of training, private sector demand, legal limitations, and Department of Defense policy—constrain the capacity of policymakers to influence this system and to shape appropriate manpower levels.

First, basic RPA training requires approximately 10 months: 5.5 months in Undergraduate RPA Training (URT) followed by 4.5 months in Formal Training Units (FTU). And even if the Air Force recruits and trains the correct number of RPA pilots, by the time these officers have completed their training, the demand for CAPs typically will have grown. Figure 1 illustrates the perennially-increasing demand for RPA CAPs and associated manpower, as ongoing military operations drove the CAP requirement from 18 in 2007 to 65 in 2014. This inflation creates a variable "moving target" each year, a distinct challenge for Air Force planners accustomed to relatively static demand in other Air Force career fields, or "Air Force Specialty Codes" (AFSCs).

The organizational heterogeneity of the Air Force poses an additional challenge for Air Force manpower planners. In fact, the USAF is divided into two discrete components: the "Active Duty Air Force" (AD) and the "Air Reserve Component" (ARC). Distinct law, policy, and resource limitations constrain the CAP contribution of either component and restrict the capacity of Air Force planners to assign additional CAPs to either one. (Of the 65 total USAF CAPS in 2014, the AD flew 49, while the ARC flew 16. Our analysis accounts for the latter contribution but focuses primarily on resolving manpower issues for the former given the greater level of demand relative to available manpower).

As an additional complication, Air Force planners must balance the manpower requirements for RPA operators with roughly 150 other AFSCs. Moreover, these planners contend with variable attrition rates among RPA pilots throughout their Air Force careers due to retirements, discharges, and transitions into other AFSCs.

Furthermore, within the population of trained and qualified RPA pilots, many of these officers are not actually available to fly operational missions. Quotas, or "authorizations," for staff and instructor positions (among other categories depicted in Table 2) further reduce the proportion of pilots available to fly operational missions. But manpower planners must be prudent with reducing these additional authorizations to devote manpower to fly operational missions, particularly with regard to instructor pilots authorizations; while the commitment of would-be instructors to fly operational missions increases combat unit manpower supply in the short-term, this limit on available trainers cripples the training system in the long-term, as the capacity to produce new RPA pilots to meet future demand dwindles.

Table 2: The table provides the distribution of Active Duty MQ-1/9 pilot quotas, or "authorizations," by job category as of October 2014.

Job	Authorization	Percent of Total
Combat Unit Pilot	490	44%
FTU Instructor Pilot	143	13%
FTU Leadership	37	3%
Test	46	4%
Staff	60	5%
Launch and Recovery	125	11%
Mission Essential Other	223	20%
Total	1124	100%

Impetus for Model

Deputy Secretary of Defense Dr. Robert Work visited Creech Air Force Base, an RPA hub, in October 2014 to examine the ground-level condition of the RPA enterprise. He heard anecdotes about manpower shortages in the RPA community which were ostensibly causing a significant sustainment challenge, particularly among combat unit pilots. Meanwhile, Headquarters Air Force established an "RPA Tiger Team" at the Pentagon to develop initiatives to revitalize the RPA manpower enterprise. Specifically, senior Air Force officials charged the Tiger Team—comprised of manpower experts, RPA pilots, analysts, and other stakeholders—with delivering actionable policy initiatives to improve manpower trends in an RPA community which was continuing to hemorrhage pilots (Majumdar 2015). We provided the analytical and modeling capability as part of this Tiger Team.

The RPA manpower shortfall was indeed dire; as of October 2014, the overall RPA pilot manning (i.e., the percentage of required manpower authorizations which were actually filled) was 80% and still declining. Worse yet, the instructor pilot manning level was below 50% of the required manpower authorizations. In early 2015, as the RPA enterprise could no longer satisfy growing global demand for CAPs, the RPA Tiger Team persuaded the Secretary of Defense that the only way to re-establish a healthy RPA community would be to reduce the total number of required CAPs. This CAP relief would afford the Air Force sufficient time to address systemic problems within the RPA enterprise. Of course, while relieving the strain on RPA manpower, this reduction in CAPs has dangerous security implications; each CAP the Air Force can no longer fly represents a real-world, global reduction in ISR coverage and Strike capability. Moreover, even with this reduction in CAPs, senior political leaders expressed concern about RPA manpower levels; for example, in a May 2015 letter to the Secretary of Defense, Senators John McCain and Jack Reed criticized the "critical manning shortfalls in this critical mission area" (McCain and Reed 2015). In the end, the message from senior defense officials and political leaders to the Air Force was clear: devise solutions to expeditiously mitigate the RPA manpower shortage.

Early Model Iteration

As of early 2015, the Air Force had not yet developed a model to project future RPA manpower. Given a short timeframe, we began our analysis by building a simple flow model to represent the subpopulation of RPA pilots assigned to fly combat missions. This model demonstrated that the crew-to-CAP ratio—i.e., the combat unit manpower assigned to fly each CAP—was 7.5 crewmembers for each CAP. (We call this metric a "7.5:1 crew-to-CAP ratio"). At this time, the *minimum* crew-to-CAP ratio was supposed to be 8.5:1, while a *healthy* crew-to-

CAP ratio was supposed to be at least 10:1. (In general, a higher crew-to-CAP ratio reflects a healthier force because it indicates that more pilots are available to fly each mission. At a higher crew-to-CAP ratio, pilots experience less strenuous flight shifts, improved focus, and higher morale. As an additional benefit, retention rates of these pilots generally improve at a higher crew-to-CAP ratio). Furthermore, the model showed that this ratio would continue to trend worse, projecting a net loss of 5 pilots per month—the equivalent of 0.5 CAPs at a healthy crew ratio—given the status quo.

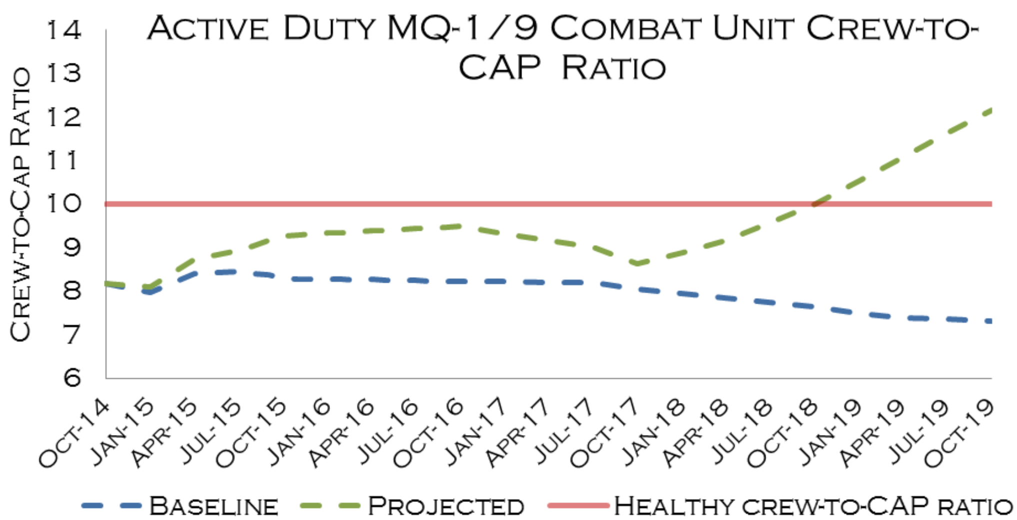

Figure 2: The dashed blue line depicts the baseline crew-to-CAP ratio projection. The dashed green line illustrates the crew-to-CAP ratio projection given implementation of Tiger Team initiatives.

With this initial model, we projected a "healthy" RPA community—i.e., an RPA community with combat units manned at a 10:1 crew-to-CAP ratio—by 2019 given the implementation of several initiatives that the RPA Tiger Team had developed. (Figure 2 illustrates this projection against the baseline projection; we explore the specific initiatives driving these projections in "Decisions Supported" below).

After presenting these initiatives and resulting projections to senior Department of Defense officials, we continued to advocate and research the feasibility of other policy options while building upon the initial modeling effort. Despite this progress, the Secretary of Defense determined that achieving a healthy RPA enterprise by 2019 was insufficient given the significance of the RPA mission. Instead, he shifted the objective for a healthy RPA enterprise forward to October 2016. Furthermore, he explicitly defined "healthy" as a crew-to-CAP ratio of 10:1 as well as a 100%-manned FTU. He tasked the Deputy Secretary of Defense with oversight of this effort, mandating that the Air Force provide weekly updates on a plan to improve the health of the RPA community as well as subsequent execution of this plan. This condensed timeframe reduced our tolerance for margin of error; therefore, we accelerated development of model enhancements and refinements to provide the necessary analytical granularity given imminent policy decisions.

Modeling Future Manpower

To achieve the analytical fidelity necessary to meet the objectives identified by the Secretary of Defense, we implemented significant revisions and extensions in the original model.

First, we expanded the model to incorporate more of the pilot population. The initial model projections only included the subpopulation of MQ pilots assigned to combat units, requiring broad assumptions regarding retention and transition rates for this subpopulation. We expanded the scope of the model to include the entire population of over 1100 RPA pilots, regardless of whether they were currently serving in a combat unit. Beyond combat unit pilots, these additional categories include leadership overhead, staff, test pilots, FTU instructors and associated overhead, and launch and recovery operations, as illustrated in Table 2. Ultimately,

the combat unit MQ-1 and MQ-9 pilots alone determine the crew-to-CAP ratio, but modeling the entire population provided greater fidelity to capture which pilots were actually available to fly missions and, relatedly, why a subset of pilots were consistently unavailable for combat mission duty.

Next, we refined the model to include three distinct subpopulations—identified in Table 3—within the greater RPA pilot inventory. Figure 3 illustrates the various ways in which these subpopulations flow through the RPA system and reflects the level of granularity with which we modeled this population. Initially, pilots flow from one of three officer commissioning sources—the Air Force Academy, Reserve Officer Training Corps, or Officer Training School—into one of two types of undergraduate flight training: Undergraduate RPA Training (URT) —for pilots designated to fly RPAs—or Undergraduate Pilot Training (UPT), for pilots assigned to fly traditional, manned cockpit aircraft. Pilots who complete URT subsequently transition into an RPA FTU, where they undergo additional RPA training before flowing into the RPA enterprise pilot inventory. (Within this pilot inventory, which is comprised of fully trained personnel, pilots might fill any of the positions listed in Table 2). Meanwhile, pilots who attend UPT have two possible routes into the RPA enterprise: either they fly manned cockpit aircraft first and then transition to RPAs, or Air Force planners assign them directly to RPAs despite that their initial training (i.e., UPT) was for manned cockpit aircraft. (The Air Force labels the latter subpopulation as “UPT-Directs”). In either case, these UPT graduates must attend an RPA FTU before transitioning into the RPA enterprise pilot inventory. Once the graduates of UPT transition into the pilot inventory, there are two possibilities: either they complete an RPA tour of approximately 3-4 years and return to a manned cockpit aircraft, or they permanently join the RPA community. (The former subpopulation of pilots is considered to be “borrowed,” while the

latter subpopulation is labeled as “re-categorized.” Table 3 provides additional details for these subpopulations).

Table 3: The table describes the three RPA pilot subpopulations.

Type	Description
“RPA-only” pilots, officially called “RPA 18X”	URT-trained pilot. (E.g., an RPA pilot who is trained to only fly RPAs).
“Re-categorized” pilots, officially called “RPA 11U/12U”	UPT-trained pilot or combat systems officer that has permanently transitioned to the RPA community. (E.g., an F-16 pilot who permanently becomes an RPA pilot).
“Borrowed” pilots, officially called “ALFAs”	UPT-trained pilot or combat systems officer who is temporarily serving in the RPA community while still affiliated with another rated community. (E.g., an F-16 pilot who flies an RPA and plans to return to the F-16 after the RPA tour).

Modeling these subpopulations separately (as opposed to considering them all to be part of a single, homogenous population) is useful because the subpopulations differ in average experience, military service commitment, expected time remaining within the RPA enterprise, and career paths. These factors influence the retention rates of each subpopulation, and we account for this variance by modeling them separately.

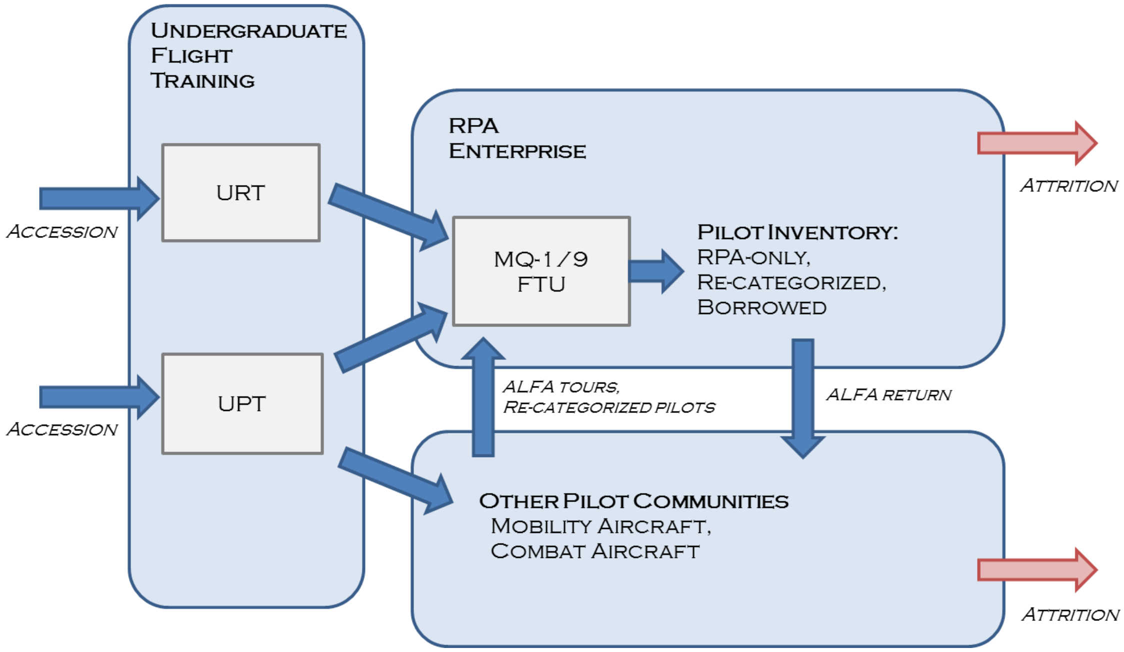

Figure 3: The diagram shows inflow and outflow of the population of RPA pilots. Each subpopulation has a distinct set of attrition rates.

We then incorporated cumulative years of military service (CYOS) into the model in order to refine the pilot retention rates used as inputs. We used historical data—combined with subject matter expert input regarding factors driving retention—to build upper and lower bounds for retention rates for each category of pilot in each year of his or her military service. With the inclusion of distinct subpopulations as well as CYOS, we built a more realistic population of RPA pilots subject to different cumulative retention rates that correspond to differences in military service commitments and stages of career. (The Appendix elucidates these differences). Figure 4 depicts all RPA pilots at the beginning of October 2014 divided according to subpopulation and CYOS.

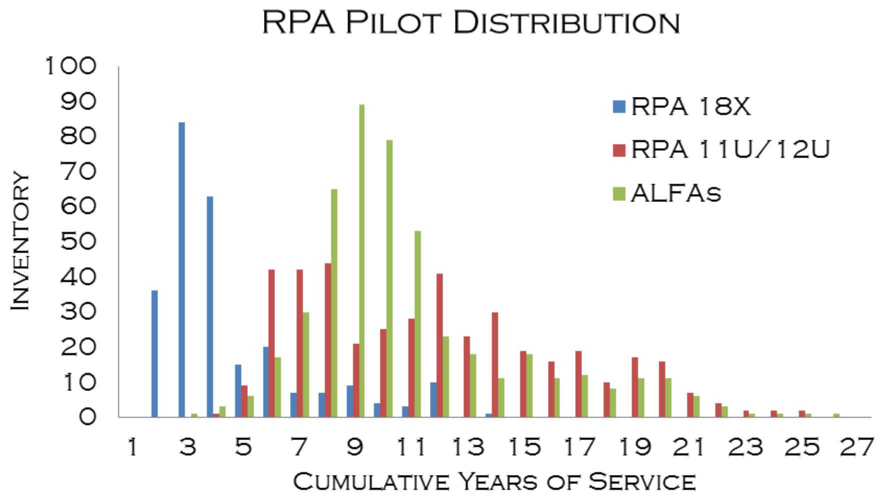

Figure 4: This chart provides an RPA pilot breakdown by subpopulation and cumulative years of military service (CYOS).

Next, we incorporated the RPA training pipeline into the model. Our initial projections had relied on simple assumptions regarding new pilot inflow. We improved these assumptions by modeling factors which influence this training pipeline capacity such as international training requirements (e.g., training for our NATO allies), ARC training requirements, additional upgrade training distinct from new pilot inflow, and a workload function to directly link available instructors to training pipeline capacity. Training pipeline capacity fluctuates constantly with these factors, so including them in the model enables more accurate projections regarding production of new RPA pilots.

In sum, by incorporating these upgrades, we built a dynamic Markovian personnel flow model which reflected real-world idiosyncrasies of the RPA manpower community with greater fidelity. We presented this refined model to stakeholders across Headquarters Air Force at the Pentagon. Once we had established a credible baseline, we began to model potential policy initiatives to compare the impacts of these new policies on the RPA community to the status quo. These analyses informed discussions in multiple meetings with senior defense officials in 2015

including the Chief of Staff of the Air Force, Secretary of the Air Force, and Deputy Secretary of Defense. Based on feedback from these discussions, we continued to build new courses of action into the model to demonstrate how additional initiatives could synchronize to most efficiently remedy the RPA manpower crisis.

Decisions Supported

Our model informed and supported several policy initiatives to achieve a healthy RPA enterprise. To satisfy the Secretary of Defense objective of a healthy RPA enterprise by October 2016, the Air Force implemented substantial—and in some cases, considerably unpopular—policy revisions. The RPA Tiger Team considered over fifty such policy options and initiatives which senior policymakers had hitherto discussed qualitatively instead of quantitatively. Our model enabled them to weigh the latter facet in their discussion and to better understand how sets of policy options would synchronize to bolster RPA manning levels. The flexible user interface of the model permitted defense officials to adjust multiple distinct initiatives, developed with input from subject matter experts, to observe the potential manpower impact given any specific subset of initiatives. In the end, Air Force officials implemented the following major initiatives to satisfy objectives articulated by the Secretary of Defense:

1) Move an average of 4 additional pilots per month to the FTU to become instructor pilots between July 2015 and October 2016. In order to increase the FTU instructor pilot manning to 100%, thereby stabilizing future RPA pilot production, the Air Force will send 4 additional instructor pilots per month to the FTU. The model demonstrated that moving precisely this number of pilots to become instructor pilots would guarantee an FTU instructor pilot manning of 100% by October 2016. (Figure 5 illustrates this projection). The model results quantified the

delicate tension between retaining combat unit pilots flying operational missions—thereby maintaining higher current crew-to-CAP ratios but hindering future production—versus moving combat unit pilots to the FTU, thereby increasing future pilot production but degrading near-term crew-to-CAP ratios. Our model optimized this movement of pilots to meet the requirements for a healthy RPA enterprise identified by the Secretary of Defense. However, with combat unit pilots moving to the FTU, we had to explore additional policy options to mitigate the adverse effect of this move on near-term crew-to-CAP ratios.

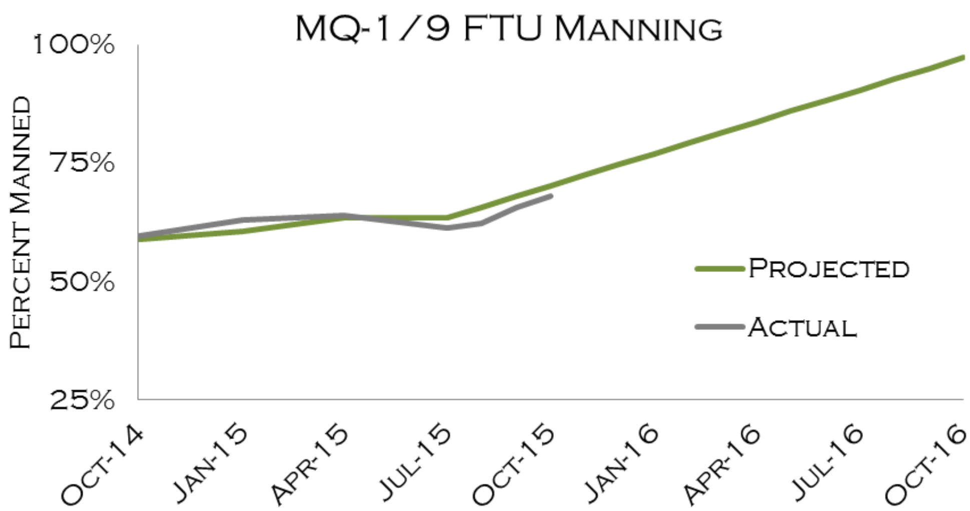

Figure 5: This graph shows the model projection of FTU manpower given 4 additional instructor pilots per month versus actual FTU manpower given real-world implementation of this initiative as of October 2015.

2) Hold ALFA pilots an additional 3 "Vulnerable to Move List" (VML) cycles. The standard ALFA tour for pilots of manned aircraft to fly an RPA lasts four years. (These pilots are the "borrowed" pilots described in Table 3). Normally, at the end of this tour, the Air Force would place the pilot on the so-called VML, a four-month window in which he or she would move to another assignment outside of the RPA enterprise. Given this policy to hold the ALFAs for an additional three VML cycles, the RPA enterprise will retain approximately 60 ALFA pilots for an additional year. Holding these ALFA pilots for an extra year enables the Air Force to shift

combat unit pilots to the FTU, as discussed above, without significantly degrading the near-term crew-to-CAP ratio.

3) Mobilize the Air Reserve Component (ARC) to fly 3 Active Duty CAPs for 2 years. Like the previous initiative, this option provides short-term relief to improve the current Active Duty crew-to-CAP ratio while pilots from combat units transition to the FTU. With this new policy, the ARC will absorb three Active Duty CAPs for two years. In order to achieve the Secretary of Defense objective of a 10:1 crew-to-CAP ratio, normally the Air Force would require 440 combat unit pilots, since the Active Duty is responsible for 44 CAPs. (Normally the Active Duty would fly 49 CAPs, but the Secretary of Defense reduced the figure by 5 CAPs, as discussed above). However, the ARC absorbing 3 CAPs reduces the Active Duty requirement to 41 CAPs, meaning the latter must commit only 410 combat pilots to these missions. This initiative further ensures that the crew-to-CAP ratio does not decline significantly in the near-term despite substantial commitment of manpower to the FTU.

4) Reduce staff positions by 15% and increase civilian contractor support. RPA pilots—and indeed most Air Force officers—covet staff positions because the experience is considered valuable for promotion to higher ranks. However, given the immediate operational strain on the RPA community, Air Force officials have nevertheless decided to limit these staff opportunities in order to commit more manpower to training and combat units. The model demonstrated that a 15% staff reduction was the minimum required to augment the other initiatives in order to satisfy the 10:1 crew-to-CAP ratio and a fully-manned FTU by October 2016. In tandem, a slight uptick in short-term civilian contractor support to the FTU—enough to represent approximately 10% of total FTU training capacity—will enable maximal training of qualified pilots from UPT and URT.

5) Send 80 additional "UPT-Directs" and 90 additional ALFAs to the RPA FTU. In order to fill all near-term vacancies in the FTU for and therefore maximize RPA pilot production, the model illuminated an additional requirement of 170 new RPA pilot candidates beyond those already produced through URT. In order to achieve this figure, based upon our recommendation, Air Force officials decided to move 80 "UPT-Directs" to the RPA FTU instead of sending them for further training in manned cockpits as originally planned. In addition, the Air Force identified 90 new ALFA tour candidates to commence training at the RPA FTU. The combination of increases in new instructor pilots as well as trainees maximizes RPA pilot production and subsequently improves the immediate crew-to-CAP ratio.

Given the implementation of these major policy initiatives, the RPA manpower enterprise should achieve a 10:1 crew-to-CAP ratio and a 100%-manned FTU by October 2016, per the direction of the Secretary of Defense. Moreover, since the initiatives which this model supports address the root cause of the manpower shortfall, the RPA community should sustain these healthy manpower figures going forward. Figure 6 shows output for the combat unit crew-to-CAP ratio projections described in this paper.

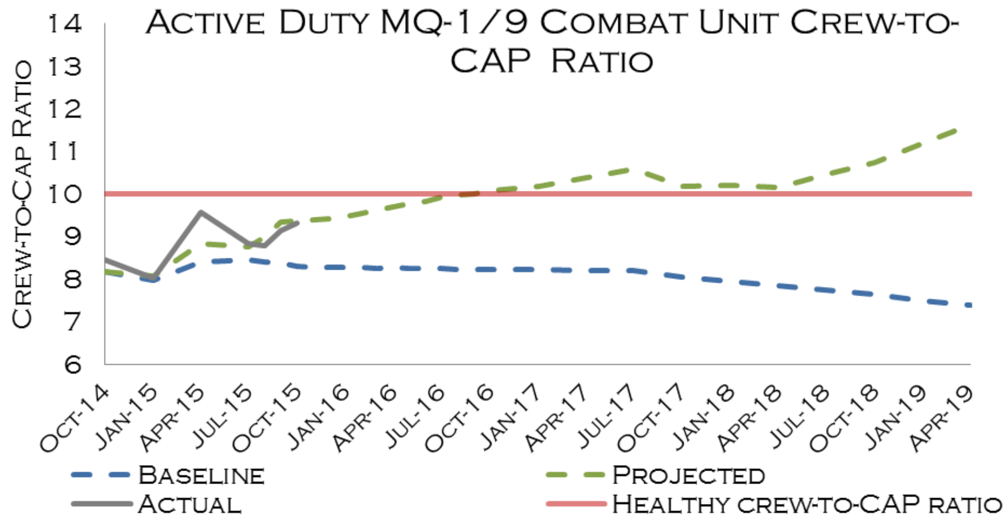

Figure 6: The green line represents a projection of RPA combat unit crew-to-CAP ratios given implementation of the initiatives outlined above plus the 5-CAP reduction. The RPA enterprise achieves a 10:1 crew-to-CAP ratio by October 2016. The blue line shows the future crew-to-CAP ratios if Air Force officials implemented no initiatives other than the 5-CAP reduction. The data are current as of October 2015.

Implementation

Given the analytical rigor underpinning the policies described above, the Deputy Secretary of Defense approved them in late April 2015 as part of a "get-well" plan which will directly impact over 1100 current RPA personnel as well as hundreds of additional airmen who will join this RPA community in the near future. The Air Force has begun to implement these initiatives; for example, as of August 2015, pilots have already received military orders to move to the FTU and to begin training to become instructor pilots. Annual production of pilot training classes for Active Duty RPA pilots should nearly double from the 2014 total. (Our model produced a precise production figure, but it is sensitive and therefore redacted from this paper).

Meanwhile, ARC forces have already received official mobilization orders according to the aforementioned initiative; the ARC mobilized to absorb one Active Duty CAP in June 2015,

with absorption of two additional CAPs planned by the end of 2015. Finally, UPT-Direct and ALFA tour candidates are already receiving military orders for training at the RPA FTU, with more to follow throughout 2016 in order to reach the figures identified in the initiative above.

While the Air Force executes these policy initiatives, we track actual manpower versus projected manpower. To ensure that the Air Force meets projections each quarter, we have established metrics including the number of Active Duty CAPs, FTU manning percentage, ARC mobilization dates, URT growth, instructor pilot movement, combat unit manning, and overall enterprise shortage. (The final metric, overall enterprise shortage, is crucial because even if the manpower level for combat units is "healthy," the overall community might still suffer from a manning shortfall in other categories like staff, test, etc.). We conducted additional analysis to show that, given our current production projections, overall enterprise health should reach 100% in all categories by April 2018, as shown in Figure 7.

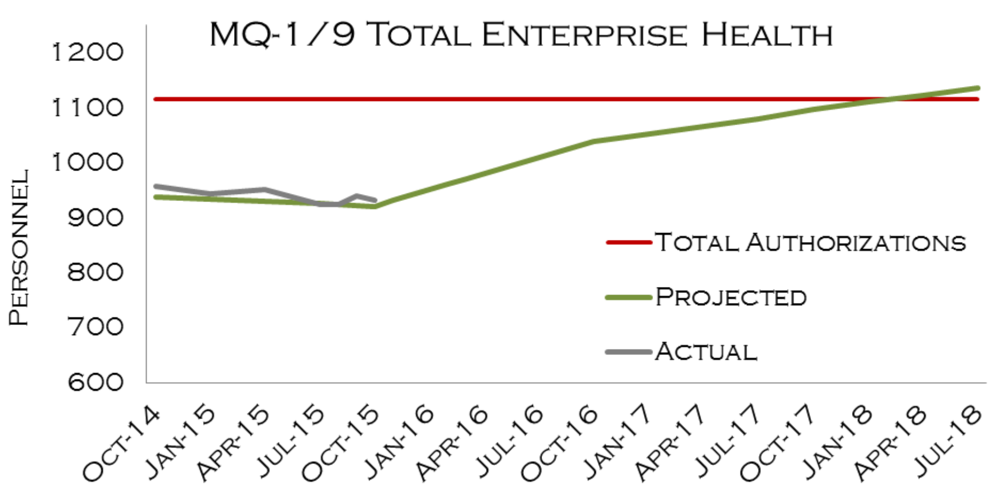

Figure 7: This graph projects that the Active Duty MQ-1/9 enterprise achieves 100% health by April 2018. We track the actual number of personnel against model projections to monitor progress. The data are current as of October 2015.

Conclusion

In this paper, we discuss our analytical approach to resolving an Air Force RPA manpower shortfall with significant combat mission implications. The output and policy changes that we have outlined reflect the timely integration of subject matter experts, analysts, and senior officials across Headquarters United States Air Force at the Pentagon. Our model, meanwhile, demonstrates the efficacy of objective analysis—in tandem with the input of military leaders and subject matter experts—to underpin Department of Defense policy. This rigorous approach has illuminated key issues in the RPA manpower enterprise and has informed a set of policy initiatives which should mitigate immediate manpower shortages in addition to providing a sustainable paradigm for the future. We look forward to tracking improvements in the RPA community and to applying this methodology to address emerging manpower issues in the United States Air Force.

Appendix

The computations and projections in the model described in this report employ the principles and mathematics of manpower stock and flow modeled as an absorbing Markov chain (Gass and Harris 2012). Given the current manning of the RPA enterprise, projecting manning for any subsequent year is determined by a combination of the manning in the previous year and newly-produced RPA pilots. All projections are based on the initial value of pilots in the RPA enterprise as of October 2014. Projecting future RPA enterprise manning is a two-fold task: first, computing overall manpower within the enterprise, and second, determining where within the enterprise the manpower is allocated. We use the following notation:

R_{18X_i}: $Percent\ of\ 18X\ pilots\ that\ are\ retained\ from\ CYOS\ i\ to\ i+1$

R_{11U_i}: $Percent\ of\ 11U\ pilots\ that\ are\ retained\ from\ CYOS\ i\ to\ i+1$

R_{ALFA_i}: $Percent\ of\ ALFA\ pilots\ that\ are\ retained\ from\ CYOS\ i\ to\ i+1$

N_{total_k}: $Number\ of\ pilots\ in\ the\ RPA\ enterprise\ in\ year\ k$

$N_{18X_{i,k}}$: $Number\ of\ 18X\ pilots\ in\ the\ RPA\ enterprise\ in\ CYOS\ i\ in\ year\ k$

$N_{11U_{i,k}}$: $Number\ of\ 11U\ pilots\ in\ the\ RPA\ enterprise\ in\ CYOS\ i\ in\ year\ k$

$N_{ALFA_{i,k}}$: $Number\ of\ ALFA\ pilots\ in\ the\ RPA\ enterprise\ in\ CYOS\ i\ in\ year\ k$

$P_{18X_{i,k}}$: $Number\ of\ new\ 18X\ pilots\ entering\ the\ RPA\ enterprise\ in\ CYOS\ i\ in\ year\ k$

$P_{11U_{i,k}}$: $Number\ of\ new\ 11U\ pilots\ entering\ the\ RPA\ enterprise\ in\ CYOS\ i\ in\ year\ k$

$P_{ALFA_{i,k}}$: $Number\ of\ new\ ALFA\ pilots\ entering\ the\ RPA\ enterprise\ in\ CYOS\ i\ in\ year\ k$

First, we describe how we compute the total number of RPA pilots in the enterprise for any future year. The total number of RPA pilots in the RPA enterprise in year *k* is given by the equation

$$N_{total_k} = \sum_{i=1}(N_{ALFA_{i,k}} + N_{18X_{i,k}} + N_{11U_{i,k}}).$$

Given the current state of the RPA enterprise, historical data, Active Duty service commitments, and subject matter expert input, we determined retention rates, that is, values for $R_{18X_i}, R_{11U_i},$ and R_{ALFA_i} for all *i*. These rates give the percent (or probability) that a pilot flying an RPA in the respective subpopulation in a CYOS is retained in the inventory for the next

year. We use two possibilities, a lower and an upper bound, for RPA 18X and “other pilot” (i.e., 11U/12U and ALFA) retention rates to compute a range of projections.

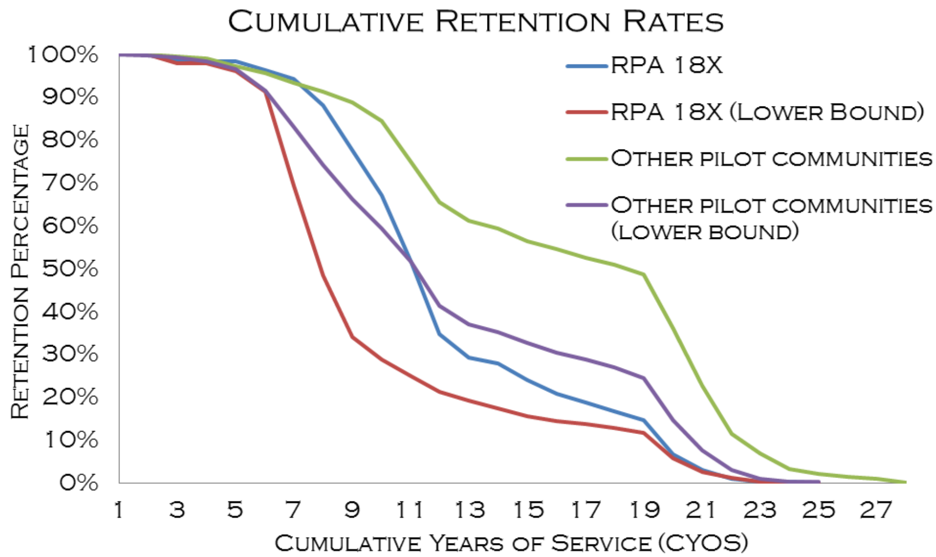

Figure 8: The graph shows the cumulative retention rates for pilots according to subpopulation. The RPA 18X population has a shorter military service commitment than other pilot subpopulations. We developed an upper and lower bound for the subpopulations based upon historical data as well as subject matter expert input on policies and factors which shaped these trends.

We compute the total number of 18X pilots in a given CYOS in year *k* recursively:

$$N_{18X_{i,k}} = R_{18X_{i-1}} * N_{18X_{i-1,k-1}} + P_{18X_{i,k}} \ \ for\ i\ \geq 2, k\ \geq 2015, and\ N_{18X_{1,2014}}\ given.$$

We use similar equations for the 11U/12U and ALFA subpopulations. We assume the following distribution for pilot production across the three subpopulations:

$$P_{18X_i} = \begin{cases} 0.4 * P_{18X_k}, for\ i = 1 \\ 0.25 * P_{18X_k}, for\ i = 2 \\ 0.125 * P_{18X_k}, for\ i = 3, 4 \\ 0.05 * P_{18X_k}, for\ i = 5, 6 \\ 0, otherwise \end{cases} \quad P_{AFLA_i} = \begin{cases} 0.2 * P_{ALFA_k}\ , for\ i = 6 \\ 0.3 * P_{ALFA_k}\ , for\ i = 7 \\ 0.4 * P_{ALFA_k}\ , for\ i = 8 \\ 0.1 * P_{ALFA_k}\ , for\ i = 9 \\ 0, otherwise \end{cases} \quad and\ P_{11U_i} =$$

$$\{0.05 * N_{ALFA_k}\ , for\ i = 7 \text{ to } 12$$

where P_{j_k} is the total production of new pilots of subpopulation *j* in year *k*. The retention rate for the ALFA pilots, R_{ALFA_i}, must be given special attention: Assuming a four-year tour, the retention from year *i-1* to *i* is given as

$$R_{ALFA_i} = R_{11U_i} - 30\%$$

where R_{11U_i} accounts for the natural attrition rate for pilots of other manned aircraft and the additional attrition (i.e., 30%) assumes 25% attrition per year to incorporate the standard four-year ALFA tour plus an additional 5% attrition per year for AFLA re-categorization to 11U/12U. The above equation is easily modified to account for policy changes which would extend the ALFA tour by any length of time. (E.g., a five-year ALFA tour would use 20% attrition per year). The equations detailed above form the basis for projecting all future RPA pilot manpower.

The second facet of projecting RPA pilot manpower is allocating the pilots in the array of possible jobs across the enterprise. Given the policy changes, as well as the deadline of October 2016 to meet the Secretary of Defense goals of a 10:1 crew-to-CAP ratio and a 100%-manned FTU, we allocate specific percentages to fill the remaining job types in the inventory. The manpower that the model allocates is less than the manpower authorized for some job types. We optimize the distribution of manpower by committing the minimum number of pilots necessary

to achieve 100% manning for combat units and the FTU before filling other authorizations. Table 4 provides this manpower distribution.

Table 4: "Authorized Percent" represents the distribution of RPA manpower by job if every authorization in the enterprise were filled. "Modeled Percent" represents the distribution of RPA manpower by job that the model actually targets for October 2016, the deadline given by the Secretary of Defense. The model initially fills combat unit and FTU authorizations as absolute numbers (as opposed to percentages) before distributing remaining personnel among the other job types. The "Modeled Percent" figures represent the highest manpower allocation possible in these categories while still meeting the primary goal of 100% manning for combat unit pilots and the FTU by October 2016.

Job	Authorized Percent	Modeled Percent
Combat Unit Pilot	44%	N/A
FTU Instructor Pilot	13%	N/A
FTU Overhead	3%	N/A
Test	4%	3.6%
Staff	5%	4.5%
Launch and Recovery	11%	10.0%
Mission Essential Other	20%	18.0%

As we model the future manpower beyond October 2016 and the inventory grows, we use the maximum of the "Modeled Percent" and the "Authorized Percent" so that no job category exceeds the latter.

Acronym List

AFSC	Air Force Specialty Code
ARC	Air Reserve Component
CAP	Combat Air Patrol
CYOS	Cumulative Years of Service
FTU	Formal Training Unit
ISR	Intelligence, Surveillance, and Reconnaissance
RPA	Remotely Piloted Aircraft
UPT	Undergraduate Pilot Training
URT	Undergraduate RPA Training
USAF	United States Air Force
VML	Vulnerable to Move List

Verification Letter

John W. Raymond, Lieutenant General, United States Air Force, Deputy Chief of Staff for Operations, Plans, and Requirements, Headquarters United States Air Force, The Pentagon, Washington, DC 20330, writes:

"Per your submission guidelines, I hereby certify that the analytical effort described in the article 'Sustaining the Drone Enterprise: How Manpower Analysis Engendered Policy Reform in the United States Air Force' informed policy decisions by the Office of the Secretary of Defense. Specifically, in regular meetings regarding Remotely Piloted Aircraft (RPA) manpower trends with Deputy Secretary of Defense Robert O. Work, Air Force general officers and other senior officials relied on analytic insights from the analysis and accompanying model described in the aforementioned article. Ultimately, this analysis underpinned several new initiatives designed to mitigate a substantial RPA manpower shortfall. I highly encourage INFORMS to accept this impactful work for publication."

Biographical Summaries

Major Kiel M. Martin currently serves as an Assistant Professor of Computer Science at the United States Air Force Academy. He previously served with Headquarters Air Force, Studies, Analyses, and Assessments from 2012-2015 as a program analyst, where he was directly involved in projects ranging from analyzing the US Air Force response under sequestration and improving enterprise-wide fleet maintenance standards to rated personnel studies, including the RPA enterprise. Maj Martin has deployed to the US Central Command Combined Air Operations Center in support of ongoing operations in the Middle East, and he previously conducted operational testing on fighter aircraft, including the A-10, F-22, and F-15E. He completed his Ph.D. in Operations Research at the University of Texas at Austin in 2012, S.M. in operations research at Massachusetts Institute of Technology in 2007, and B.S. in operations research and mathematics from the United States Air Force Academy in 2005.

Daniel J. Richmond has been an analyst with Headquarters Air Force Studies, Analyses, and Assessments for the past year. In this capacity he has led or been a part of studies ranging from manpower and resource allocation to modeling and predicting expected aircraft attrition over a defense threat environment. He completed his Ph.D. in mathematics at The University of Rhode Island in 2014, M.S. in mathematics at The University of Rhode Island in 2011, and B.A. in mathematics with a minor in physics from Stonehill College in 2009.

Captain John G. Swisher currently serves as a Lecturer, Department of Aerospace Studies, Yale University as well as Operations Flight Commander for Air Force ROTC at Yale. In this capacity, he leads over sixty cadets in a military training program and lectures on topics ranging from leadership and communication to military history. In addition to his previous role as an Operations Research Analyst at Headquarters U.S. Air Force at the Pentagon, he has served

on a Congressionally-mandated Federal Advisory Commission and deployed to Eindhoven, The Netherlands in support of NATO operations in Afghanistan. He holds a B.A. in Mathematics and Philosophy from Yale and graduated with honors from the Operations Research Systems Analyst Military Application Course at Army Logistics University.

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